Towards Improving the Quality of Present MAC Protocols for LECIM Systems

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***Abstract*—Wireless networking system is quickly growing in the field of communication technology due to its usefulness and huge applications. To make the system more effective to the users its lower energy consumption, security, reliability and lower cost issues must be considered under any circumstances. Low energy wireless is exceedingly required because the sensors are frequently located where mains power and network infrastructure are not reliably available. The recent development of Low Energy Critical Infrastructure Monitoring (LECIM) has vast applications including: Water leak detection, Bridge/structural integrity monitoring, Oil & gas pipeline monitoring, electric plant monitoring, public transport tracking, Cargo container monitoring, Railroad condition monitoring, Traffic congestion monitoring, Border surveillance, Medical alert for at-risk populations and many more. This proposal Low Energy Critical Infrastructure Monitoring (LECIM) is proposed by the Task Group 4k under IEEE P802.15 WPAN. Although many issues related to its quality are involved, but several Media Access Control (MAC) protocols with different objectives were proposed for LECIM. In this research paper, issues related to energy consumption and wastage in LECIM system, energy savings mechanism, relevant energy conscious MAC protocols have been briefly studied and analyzed. Science Direct, Elsevier, Springer, IEEE Explore, Google Scholar and Wiley digital Library databases were used to search for articles related to the existing MAC protocols well suited for LECIM system. Finally, some ideas have been proposed towards developing energy efficient MAC protocol for LECIM applications in order to fulfill and satisfy the major issues of LECIM quality.**

Keywords*—wireless networking; LECIM; IEEE P802.15; WPAN; MAC

I. Introduction

In the practical point of view the usefulness of wireless sensor networking (WSN) system requiring certain criteria including lower energy consumption, security, reliability and lower cost. Low energy wireless is particularly required because the sensors are commonly located where mains power and network infrastructure are not reliably available. The recent development of Low Energy Critical Infrastructure Monitoring (LECIM) has vast applications including: Water leak detection, Bridge/structural integrity monitoring, Oil & gas pipeline monitoring, electric plant monitoring, public transport tracking, Cargo container monitoring, Railroad condition monitoring, Traffic congestion monitoring, Border surveillance, Medical alert for at-risk populations and many more. Low Energy Critical Infrastructure Monitoring (LECIM) is proposed by the Task Group 4k under IEEE P802.15 WPAN.

Although many issues related to developing efficient LECIM applications can be summarized like, protection of the sensed data, accessing the shared medium in LECIM network; endpoints sleep time; proper coordination between coordinator and endpoints basically the way of knowing how the endpoints will know that the coordinator wants to send them the data is a challenging job where battery power must work for several years; lack of energy conservation mechanism related to its quality are involved, where most of the existing MAC protocols that support wireless sensor networks can't support these issues properly; formative the status of the channel, in LECIM this is very important because most of the nodes in LECIM system are situated in long distance and the distance among the nodes are also long, the large number of endpoints are also a significant factor. In order to solve this problem the existing contention-based and scheduled-based MAC protocols are not the appropriate solution, it needs to give more attention to solve the above mentioned problems. In this paper, we are expecting to analysis and propose some new ideas for improving MAC protocol for LECIM system, which could fulfill and satisfy the major issues of LECIM quality.

The rest of the paper is structured as follows. In Section II, major challenges, constraints and characteristics of low energy critical infrastructure monitoring; in Section III, sources of energy wastage in LECIM system are studied; in Section IV, we discussed communication patterns and energy consumption measuring system; in Section V, we discussed some mechanisms to reducing energy wastage in LECIM; in Section VI, major MAC requirements for LECIM system are defined, in Section VII, MAC protocol types in applications of LECIM system are briefly discussed; in Section VIII, we proposed some ideas for improving better performance and energy efficiency in MAC for LECIM system. Finally, we concluded and discussed future work in Section IX.

II. Major Challenges, Constraints and Characteristics of Low Energy Critical Infrastructure Monitoring

Efficient LECIM network including its infrastructure and applications is the important issue for LECIM system. The IEEE TG4K group facilitates single point to several thousands of point's communication for critical infrastructure monitoring containing one coordinator and multiple end points. In this process, coordinator is mains powered and end points are battery powered [1] [2]. The main characteristics and challenges for LECIM system is illustrated in the following Table I [3] [4] [5].

TABLE I. CHARACTERISTICS AND CHALLENGES FOR LECIM SYSTEM

LECIM Requirements Types	Major Characteristics and Challenges
Requirements based characteristics: Low energy, long lifetime, scalability, reliability, availability, robustness, maintainability, and security are network based requirements, where large path loss, minimal infrastructure requirements, and multi-year battery life are applications based requirements.	Simultaneous operation for at least 8 co-located orthogonal networks
	Application data rate vary from 1 to 40 kbps
	Propagation path loss of at least 120 dB
	Communication between main-powered coordinator and large number of endpoints, >1000 endpoints per mains powered infrastructure
	Asymmetric application data flow. Data flowing from all or a group of sensors to the central unit and vice versa.
	Ultra-low maintenance traffic
	Low power consumption, end point need to periodically go to sleep to conserve energy
	High channel access efficiency is required
	Primarily outdoor environment with minimal network infrastructure
	Long deployment life with/ without human contact (long lived infra more than 10 years life like network carrier's infra, ease maintained monitoring network, high degree of freedom to start the monitoring/maintenance business)
	Need low energy operation necessary for multi-year battery life (>20 year)
	Tolerant to data latency
	Small, infrequent messages
	Network devices: Coordinator (Collector) typically mains powered (rarely available). End point devices are typically battery powered (Battery operation (up to 20 years), low energy consumption, Low duty cycle). No mobility of end devices but portability for coordinator. High network dynamics.
	Low node density(long range)
	Mobility (Asset tracking, Dynamic fail-over)
	Worldwide use(Operates in all regulatory domains, Low transmit power compliant with international regulations)
	Low cost(Low operational cost: unlicensed, lightly licensed spectrum, Low infrastructure, maintenance , and system cost, Ease of deployment)
	Small device with high applications dependence, with limited memory, computing, transmitting and limited energy resources.
	Must be compatible with existing MAC
	PHY packet size for LECIM: Typical packet duration "real world" ranges from < 1ms to ~16ms
	Aim to collect the scheduled and event data
	Aim to minimize the network maintenance traffic and endpoint active durations
	Aim to collect real time and non-real time data
	Communication patterns: Periodic, event-based and query-based

III. STUDY AND ANALYSIS OF SOURCES OF ENERGY WASTAGE IN LECIM SYSTEM

Major sources of energy waste of low energy critical infrastructure monitoring (LECIM) based on wireless sensor network (WSN) at medium access communication are depicted in the following Table II.

Sensor node in WSN, the main sources of energy consumption, is divided into three activities including (a) sensing, (b) computation (data processing), and (c) radio operations or communication. Out of those three sources, energy loss due to radio operation or communication for data transmission is the maximum one where energy consumed for radio transmission is directly proportional to distance [6] [7] [8].

Energy waste through communication depends on sensor nodes include theses technological and physical characteristics such as collision, overhearing, control packet overhead, over emitting, idle listening, traffic fluctuation, packet forwarding, excessive state changes of the radio circuit, increased latency [9]-[13]. It's notable that, idle listening is a major cause of energy waste [14].

TABLE II. STUDY AND ANALYSIS OF SOURCES OF ENERGY WASTAGE IN LECIM SYSTEM

Source of Energy Wastage	How Energy Is Wasted?
Collision	In any event where multiple frames are received at the same time, it may damage the resulting signal and may also cause to loss all information, which requires re-transmission of collided packets. Collision results in wasted energy.
Overhearing	Message or packets are transmitted to wrong destination/nodes where its original destination is other nodes. Overhearing results in wasted energy.
Idle Listening	Occurs when the radio of the node is always on and listening to idle channel or medium even while there is no transmission. This is another source of wasting energy.
Over emitting	Messages or packets are continuing to transmit even when the destinations are not ready for receiving them; as a result, energy for sending the message is wasted.
Control Frames Overhead	Control data or frames or packets containing protocol information which are transmitting or exchanging instead of application data. Energy is consumed for transmitting and receiving these frames within medium or channels. This results in wasted energy.

IV. STUDY AND ANALYSIS OF SOURCES OF ENERGY WASTAGE IN LECIM SYSTEM

Several communication models namely broadcast, converge-cast and local gossip in WSN has been used for short and long distance based applications [15]. Transmitting necessary information to all the sensor nodes of the network a broadcast pattern is used by a sink node; in converge-cast pattern a group of sensors communicate to a specific sensor; and the sensors that detect an event communicate with each other locally is defined by local gossip pattern. Energy consumption in communication pattern depends upon its operating states which are divided into four sub-states namely transmit state, receive state, idle state, and sleep state. Transmit and receive states are used for sending and receiving data; the default state of WSN is idle state, and sleep state consumes very less energy than any other above mentioned states [16] [17]. Average power consumption of different sub-states in operating state is defined by the following ratio [18]: Transmit: receive: idle: sleep= 40.25%: 29.1%: 25.3%:5.4%

Total energy consumption ‘E’ in operating state to transmit ‘k’ bit is illustrated by the following equation [19]:

$$E = Pactive \times Tactive + Psleep \times Tsleep + Ptransient \times Ttransient + Pidle \times Tidle \quad (1)$$

Where Pactive , Psleep , Ptransient , Pidle are the power consumption and Tactive , Tsleep , Ttransient , Tidle are the interval or duration of time that a transceiver waits or stays at its active, sleep, transient and idle mode respectively.

V. Mechanism to Reduce Energy Wastage in LECIM

In order to increase network’s life time and maximizing node in LECIM it’s very important to reduce energy waste throughout the system and to enhance the performance of medium access control (MAC) protocol. Different wake up mechanisms could be used to enhance the performance of MAC protocol. Due to the unlimited power consumption of nodes in LECIM and long duration of operation energy efficiency is an important issue. It is generally not possible and practical to recharge or replace the exhausted batteries for sensor nodes in the network. So enhancing the lifetime of network as well as the sensor nodes means enhancing batteries life time.

As discussed earlier the energy consumption in sleep state is lower than idle listening state, so another good mechanism would be to maximize sleep period of the node in MAC layer, while conserving the highest throughput, the lowest latency, and the utmost energy conserving in a WSN [6]. In order to save the transmission energy, several techniques are being used including, energy-aware routing pursuing multi-hop paths, providing time-based medium access control (MAC) by limiting the potential for collisions and minimize the energy consumed in the receiver by turning the radio off when it is idle [20]. Power savings mechanism in MAC layer is classified into three basic classes and they are: effective use of the PHY layer services, optimized media access protocol structure, and useful system design [21].

The power or energy saving mechanisms [22] [23] is illustrated in Table III. Idle listening is the major cause of energy waste, so it is important to introduce suitable MAC protocol which can reduce or prevent energy wastes due to idle listening. Four techniques are being used to avoid idle listening including static sleep scheduling, dynamic sleep scheduling, preamble sampling, and off-line scheduling. Several MAC protocols are already been introduces based on these techniques which are broadly classified into: CSMA, TDMA, hybrid and cross-layer optimization [14]. Using the mechanism mentioned in the following Table IV we can easily measure the performance of energy conscious MAC protocol [24]. In LECIM system the main goal of MAC protocol is to minimize the energy waste due to idle listening, overhearing and collision.

TABLE III. CLASSIFICATION OF ENERGY SAVINGS MECHANISMS

Energy saving mechanisms	Activity
Adaptive duty cycling protocols	Reduction energy communication waste. Reducing idle listening through Duty cycling.
Wakeup on-demand protocols	Reduction energy communication waste. Reducing idle listening.

TABLE IV. MECHANISM TO MEASURE THE PERFORMANCE OF ENERGY CONSCIOUS MAC PROTOCOL

Matrices	Explanation
Energy consumption per bit	$\frac{\text{The total energy consumed}}{\text{total bits transmitted}}$, this is the proper way to define energy efficiency of the sensor nodes. The unit of energy efficiency is joules/bit. The lesser the result of ration, the better is the efficiency of a protocol in transmitting the information in WSN by satisfying all the major sources of energy waste in WSN including sleep and idle listening, collisions, overhearing, control packet overhead, message passing, etc.
Average Delivery Ratio	The average packet delivery (ratio) is $\frac{\text{the number of packets received over all the nodes}}{\text{the number of packets sent over all the nodes.}}$
Average Packet Latency	The average time requires by the packets to reach to the sink node.
Network Throughput	The total number of packets delivered at the sink node per time unit is defined by network throughput.

There are many reasons behind energy consumption in LECIM in WSN as explained earlier. Based on these reasons as mentioned in Table I some approaches are also proposed which are illustrated in Table V below. Approaches those have been proposed in many research papers for wireless systems in general can easily be added to a large variety of WSN MAC protocols.

TABLE V. APPROACHES TO REDUCE ENERGY CONSUMPTION

Approaches	Description
Reducing Collisions	CSMA/CA (CSMA/Collisions Avoidance) [25]: to avoid the collision prior to data transmission CSMA/CA exchanges RTS (Request To Send) and CTS (Clear To Send) packets. Due to the small size of RTS packets, the probability of them colliding is low. The improve version of CSMA/CA is MACA (Multiple Access Collision Avoidance) which adds a random back-off time before the transmission of RTS packet to avoid collisions. [26]. Both the above mentioned techniques aim at reducing collisions by equally trying to protect all transmitted packets.
Reducing Overhead	CSMA/ARC (Adaptive Rate Control) [26]: it omits the RTS/CTS exchange technique or avoids using RTS/CTS altogether for reducing the overhead and applies a back-off that is shifted according to the application periodicity while ensuring fairness between the forwarded traffic and the generated traffic.
Reducing Overhearing	PAMAS (Power-Aware Multi-Access with Signaling) [28] is based on MACA. PAMAS uses separate channel for RTS/CTS exchange where during transmission an unused node may switch off its radio to avoid overhearing.
Reducing Idle Listening	The IEEE 802.11 PSM (Power Save Mode) [29] for BSS (Basic Service Set) is a good approach for reducing idle listening which ultimately saves unnecessary energy waste in wireless networks. It places nodes to sleep as much time as possible for avoiding and reducing overhearing and overhead.

VI. MAJOR MAC REQUIREMENTS FOR LECIM SYSTEM

A different computation and communication infrastructure is provided by WSN which is based on both physical characteristics including the large scale of deployment, inadequate computing capability, and limitations on power consumption; and typical applications including tracking objects or detecting events. As a result, the requirements for the MAC layer of a LECIM system in WSN are clearly different from those for traditional networks [30]. The major requirements for the MAC layer in a LECIM system [31] should be as follows as depicted in Table VI.

TABLE VI. MAC REQUIREMENTS FOR LECIM SYSTEMS

Objective	MAC Requirements
An efficient MAC protocol for LECIM in WSN should contain these attributes	Assured and secured link access on low duty cycle with low energy.
	Maintain and support to fair access between nodes.
	Avoiding contention-based protocols (control packets overhead and active sensing of the medium are performed by these protocols) to minimize contention on a link (distribute access loads on slotted link) which is inefficient in terms of energy consumption.
	Time-stamping (global time synchronization, adjust clock drift with light overhead)
	Support to ease installation and maintenance.
	Support to make network structure simple
	Optimized to network configuration
	Real-time or Quality-of-Service (QoS) requirements: due to the importance of data availability and transmission requirements including timely detection, processing, and delivery of data in wireless applications the MAC layer should support real-time guarantees or QoS features in WSNs.
	Scalable and decentralized protocol: due to the large scale of sensor network and a large set of sensor nodes in the networks the most algorithms running in WSNs need to be decentralized.
	Power aware: due to the idle mode of operation and transmission overhearing among sensors there is a possibility of power consumption in WSNs and it needs to deploy MAC protocol to save power consumption by putting the node to sleep to save power.
	Collisions should be avoided because it causes energy wastage due to packet drop (thus reduce throughput).
	Packet drop should be prevented.
	Flexibility: MAC layer of WSNs should adopt a variety of network traffic patterns including rate-based or burst; reliable or best effort, etc these networks are often application specific.

VII. MAC PROTOCOL TYPES IN APPLICATIONS OF LECIM SYSTEM

Low energy consumption is the major issue in any wireless application including LECIM. Therefore designing, implementation and performance of energy efficient MAC protocol is a vital issue. Contention-based MAC protocols don't allow communication traffic (flow according to a preset schedule) that's why it's a major concern of large energy consumption, but a time division multiple access (TDMA) based MAC allows communication traffic which reduces energy consumption and extends the life of WSNs. In these time-based MAC enabled WSNs, the nodes can turn off their transmitters or receivers whenever it requires and collision among nodes can also be avoided because each of the nodes has its own time slots which reduce wastage of energy in communication. [32] [33]. The way of prolonging the network/node lifetime in LECIM depends on energy efficient MAC protocols including synchronous MAC protocols and asynchronous MAC protocols. Energy waste is reduced in synchronization because in this mode nodes keep awake only at a specified time and also synchronous protocols maintain a schedule, where, sensor nodes independently schedule their awake period in asynchronous MAC protocols to periodically check the channel while avoiding the synchronization overhead and introducing long latency and excess energy consumption [34]-[36].

There are five categories of MAC protocols specifically designed for WSNs as mentioned below: 1) Scheduling based or contention free or reservation based or cluster based MAC or channel partitioning MAC or controlled access protocol; 2) Collision free MAC protocols; 3) Contention based or channels polling or low power listening or cycled receiver or random access MAC or preamble sampling; 4) Scheduled-contention based MAC protocols or common active period protocol; and 5) Hybrid schemes or protocols.

The three most suitable MAC approaches to designing an energy efficient MAC protocols are Channel Polling (Low power listening-LPL), Scheduled contention, TDMA – contention free /cluster-based MAC protocols [37-38].

In the upper portion of both tables, Table VII, Table VIII and Table IX as mentioned bellow present the characteristics of the LPL, schedule-contention, and TDMA mechanisms for wireless sensor network based applications [37-47].

As mentioned, most of the existing MAC protocols are designed for a single channel only, they do not operate on Multi-PHYs simultaneously. Since different bands have different characteristics in terms of data rate, number of sub-channels in a particular frequency band/channel, and data prioritization where a good MAC protocol for LECIM should enable reliable operation on MICS, ISM, and UWB etc bands simultaneously, hence MAC transparency has been a hot topic for the MAC designers [48]. Energy saving or energy consumption issue in LECIM MAC is related to synchronous or asynchronous, beacon or preamble, and different periods of wake up and sleep modes. Idle listening dominates the total energy consumption in conventional power management schemes which is based on either periodic wake-up or sleep schedules. Sleep mode power consumption is much less than idle power consumption, which is near to 0.003 mW [49].

The MAC protocols discussed in Tables (VII-IX) in most of the cases cannot satisfy all the requirements of LECIM. Most of the traditional MAC protocols don't focus on energy conservation a mechanism which is one of the most important requirements of LECIM; they mainly focused on bandwidth utilization and throughput. On other hand contention-based protocols are used to determine the status of the channel supported by, however, this is not always guaranteed in LECIM due to the long distance among the nodes. However scheduled-based protocols provide good solutions for clear channel assessment problems, but due to large number of endpoints and event based traffic these are also not suitable for LECIM. MAC using wakeup radio is also proposed for better communication in LECIM networks.

Large network size, scalability, energy consumption issue including idle listening and delay, long battery lifetime, and security must be the major design issue for constructing any MAC protocol for LECIM.

VIII. Proposed Ideas to Ensure Better Performance and Energy Efficiency in Mac for Lecim

a) MAC Protocol with adjustable sensor Sleep Mode.

b) Reduced idle listening based medium access control (MAC) protocol: idle mode of operation should be minimized.

c) Periodic wake-up and listen technique for sensor network.

d) Collision and overhearing avoidance: Interfering nodes go to sleep after they hear an RTS or CTS packet. Collision leads to packet drop, thus reduce throughput and cause energy wastage.

e) Communication and transmission overhearing among sensors must be minimized.

f) Maintaining synchronization: synchronization required for the listen and sleep schemes among neighboring nodes.

g) Proper radio network architecture (diversity) for improving communication reliability in application in wireless sensor network based on heterogeneous and time-varying environmental conditions.

h) Introducing newly evolved communication pattern e.g. communication pattern multicast, in this pattern a sensor sends a message to a specific division or subset of sensors.

i) Introducing energy efficient buffer size of sensors. Packet drop should be prevented due to inadequate or limited buffer capacity causes high energy consumption.

j) Protocol should adapt to changes in network topology.

k) Ensuring reliable transmission with better maintenance of latency.

TABLE VII. THE MAJOR CHARACTERISTICS OF LOW POWER LISTENING-LPL MAC PROTOCOL, AND A WIDESPREAD STUDY OF THE EXISTING PROTOCOLS IN THE PERSPECTIVE OF ENERGY EFFICIENCY FOR LECIM

Channel polling or Low Power Listening-LPL LPL is unable to contain or accommodate a periodic traffic and low duty cycle nodes in wireless sensor network based applications.					
Channel polling or Low power listening (contention based LPL)				**Scheduled listening and LPL**	
Major reasons of energy wastage in contusion based LPL including: a. node periodically wakes up, b. turns radio on and c. checks channel. Result: low energy wasted on idle listening, and high energy wasted on transmissions (long preambles). Limitation: Overhearing-non-targeted receivers who sample the channel during preamble transmission have to wait until the end of the preamble to go back to sleep. Energy expenditure is a function of density as well as traffic load, where entire preamble needs to be sent before data transmission.				In terms of throughput and delay it provides a good transaction between energy consumption, complexity and performance. It attains the benefits of scheduled MAC protocols because of its simple operation of unscheduled MAC protocols, as well as the low consumption and cost-free maintaining and sharing the schedule.	
Channel polling or low power listening-LPL (contention based) MAC protocols: Adaptability to LECIM					
WiseMAC	**B_MAC**	**TICER/ RICER**	**STEM**	**X-MAC**	**A MAC Protocol using a Wakeup Radio: M.J. Miller, others**
1. Organized randomly, 2. well for high traffic applications 3. it supports mobility, 4. Min/ low and max/ high power consumption in low and high traffic conditions, 5. Finally, low delay.	1. Low power Consumption on MAC Protocol. 2. Nodes wake up and perform channel sensing periodically 3. Good for high traffic application 4. Energy wasted due to idle listening and transmissions (on link preamble)	1. Significant decrease/ reduction of power consumption if wake up period is optimal. 2. Permit efficiently trade-off between energy and latency	1. Good for periodic traffic especially for low traffic applications. 2. Appropriate to handle irregular sporadic events due to a divide or separate control sub-channel. 3. Difficult to handle irregular events when the transfer or traffic loads are high.	1. Evade overhearing problem. 2. It saves energy at both the transmitter and receiver because of its strobe preamble approach 3. It allows for lower latency	1. It reduces energy consumption. 2. Outperforms STEM in energy efficiency and latency.
Proposed protocols for scheduled listening and LPL					
Scheduled Channel Polling MAC (SCP-MAC): Hybrid approach			Receiver Initiated MAC: RI-MAC		
1. It coordinates and synchronizes neighbor's channel polling time. 2. Reason of energy saving: a short wake up tone wakes up receiver. 3. Advantage: it is efficient for both unicast and broadcast packets.			1. It minimizes idle overhearing in dense networks. 2. Advantages: Sender does the idle listening, and receiver transmits beacons.		

TABLE VIII. THE MAJOR CHARACTERISTICS OF CONTENTION-BASED MAC PROTOCOL AND A COMPREHENSIVE STUDY OF THE EXISTING PROTOCOLS IN THE CONTEXT OF ENERGY EFFICIENCY IN LECIM

Scheduled-contention/ contention based MAC Protocol/ Random access MAC				
Basic characteristics including: 1. Contention-based MAC such as Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) protocols nodes competes for the channel to transmit data. 2. In this scheduled-contention method, nodes must perform clear channel assessment (CCA) before transmission of data. 3. In this mode, if the channel is busy, the node defers its transmission till it becomes idle. Main reasons of energy (extra) consumption: 1. In a scheduled-contention mechanism, both schemes are combined to gain scalability and to avoid collision during transmission 2. In this mechanism, the nodes become accustomed a common schedule for data communication. 3. During a synchronization period of this mode schedules are exchanged periodically. 4. If two neighboring nodes reside in two different clusters, they keep the schedules of both clusters resulting in extra energy consumption. 5. Listening for full contention period, even listening before transmitting. 6. Although the mechanism is synchronous, but low duty cycle nodes don't need frequent synchronization/exchange of schedules in wireless sensor network based applications.				
Existing contention-based MAC protocols: Adaptability to LECIM				
Sensor-MAC (S-MAC)	**Pattern-MAC (PMAC)**	**Timeout MAC(T-MAC)**	**Dynamic Sensor-MAC (DSMAC)**	**Sleep Scheduled Delay Efficient (DESS)**
Major issues including: 1. Low throughput, overhearing and collision may cause if the packet is not intended to listening node. 2. Good for high traffic	1. Adjustment and adaptation to changes and modification might be slow 2. Loosely synchronized 3. High throughput under	1. Improved version of SMAC. 2. It does not use fixed active period. But it has the capability to abridge or shorten the active period if the channel	1. Better delay 2. Using dynamic sleep scheme to save energy.	1. Enhanced or improved delay for the topology like: grid and tree 2. Random or arbitrary topology is not guaranteed even by better delay.

applications. 3. Appropriate for applications where throughput is not a principal concern e.g. in-body medical applications.	heavy traffic. 4. Good for delay-sensitive applications.	is idle for a short time. 3. In this mode, in the case of data, the node remains active till data reception or until the active period ends. 4. In this mode better delay, and gives better result under variable load, because packets are sent in burst, 4. Excellent for high traffic applications. 5. The nodes may lose synchronization due to its early sleep problems.		3. This mode is loosely and insecurely synchronized.

TABLE IX. THE MAJOR CHARACTERISTICS OF SCHEDULED-BASED MAC PROTOCOL AND A COMPREHENSIVE AND WIDESPREAD STUDY OF THE EXISTING PROTOCOLS IN THE CONTEXT OF ENERGY EFFICIENCY FOR LECIM

Scheduled-based/ contention-free/ cluster-based MAC Protocol			
Basic characteristics including: 1. Time Division Multiple Access (TDMA) is a schedule-based or contention-free of cluster-based multiple access technique 2. In this technique transmission of packets are administered in the form of time frames and time slot. 3. In this mode, a time slot can be seen as a devoted transmission resource. It's used to carry data with minimum or no overhead. 4. In this technique, the channels are particularly divided into fixed or variable time slots which are assigned to a particular sensor node to transmit during its slot period. 5. In this protocol, nodes are collision-free because slots are pre-defined and allocated to individual nodes at the beginning, 6. It requires a good synchronization scheme. 7. There are no idle listening and overhearing issues are visible in this protocol due to its reduced duty cycle mechanism. 8. It is found that Scheduled-based/ contention-free/ cluster-based MAC Protocol is more appropriate for non-dynamic type of networks (with a limited number of sensors generating data at a fixed rate). Reasons behind energy efficiency: 1. Time division multiple access (TDMA) or schedule-based protocol can easily support low duty cycles, which is one of the important reasons of energy efficiency. 2. It can easily avoid usage of extra energy that leads reducing energy waste from all major sources [collision, idle listening etc.]. 3. Having low duty cycle nodes it doesn't require frequent or regular synchronization at the beginning of each super-frame.			
Existing scheduled-based MAC protocols: Adaptability to LECIM			
Flow-Aware Medium Access (FLAMA)	**LEACH**	**PACT**	**Ultra low power MAC or BSN MAC**
Main characteristics including: 1. Low delay 2. Superior end-to-end reliability 3. Remarkable energy savings. 4. It requires more support for multiple channels 5. Requires time synchronization 6. Good for low-power applications 7. Adaptable to high traffic applications.	1. It is distributed, 2. It doesn't require any global knowledge 3. Extra overhead for dynamic clustering. 4. Network's coordinator can perform/ act as a cluster-head (depending on minimum communication energy).	1. Major characteristics including, high traffic overhead 2. Idle listening 3. Requires (lacks) support for dynamic network 4. Low overhead 5. Expanded/ prolonged network lifetime 6. Good for low delay applications	1. It is an adaptive, feedback-based MAC protocol. 2. It is an IEEE 802.15.4-compatible MAC protocol. 3. Better performance in energy efficiency and latency. 4. Better in energy critical nodes. 5. MSN-MAC can improve the energy efficiency and prolong sensors' life time.

IX. CONCLUSION

In this paper, the researchers have presented issues related to energy consumption and wastage in LECIM system, energy savings mechanism. We have also studied and analyzed LECIM relevant energy conscious MAC protocols. Finally, some recommendations have been proposed for developing energy efficient MAC protocol to satisfy the major issues of LECIM quality.

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